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EP 0388249 A2 EP 0376509 A1 US 5388432 A
US 5069703 A US 4556408 A US 4556407 A
US 3163514 A

(58) Field of Search
UK CL (Edition O) C1M MHF MHM MJD
INT CL^6 C03B 23/023 23/025

(54) Frame and oven for sag-bending glass

(57) A thermally inert frame (pref. calcium silicate) for supporting a sheet of glass (4) which is to be bent (eg: to make a windscreen) by the action of gravity on the sheet when placed in an oven or lehr. The periphery of the sagging glass comes to rest on a plurality of spaced apart support heads (6) arranged on curved side members (2a, 2b), said support heads being constructed of a heat transfer material (eg: a metal) and having a small surface area. To minimise marking of the bending glass where it contacts the support heads, the heads are preferably covered with ceramic paper. The oven features a curved roof (8), curved floor (9), and a number of infrared heating elements (10) which direct more heat towards the edges of the glass sheet than to the centre, producing a curved glass sheet with the desired properties.

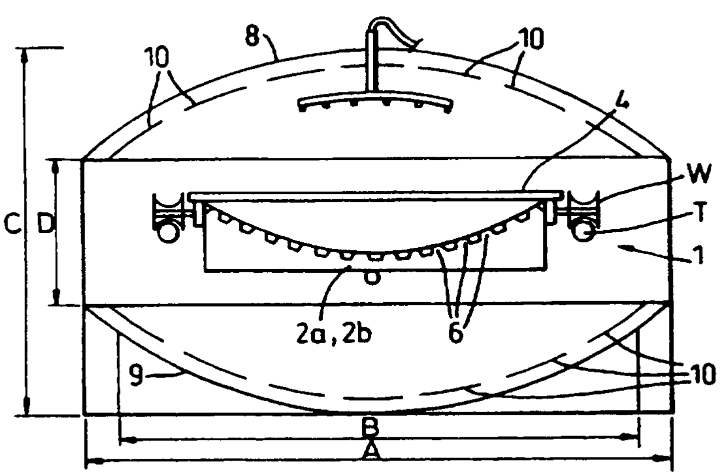

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

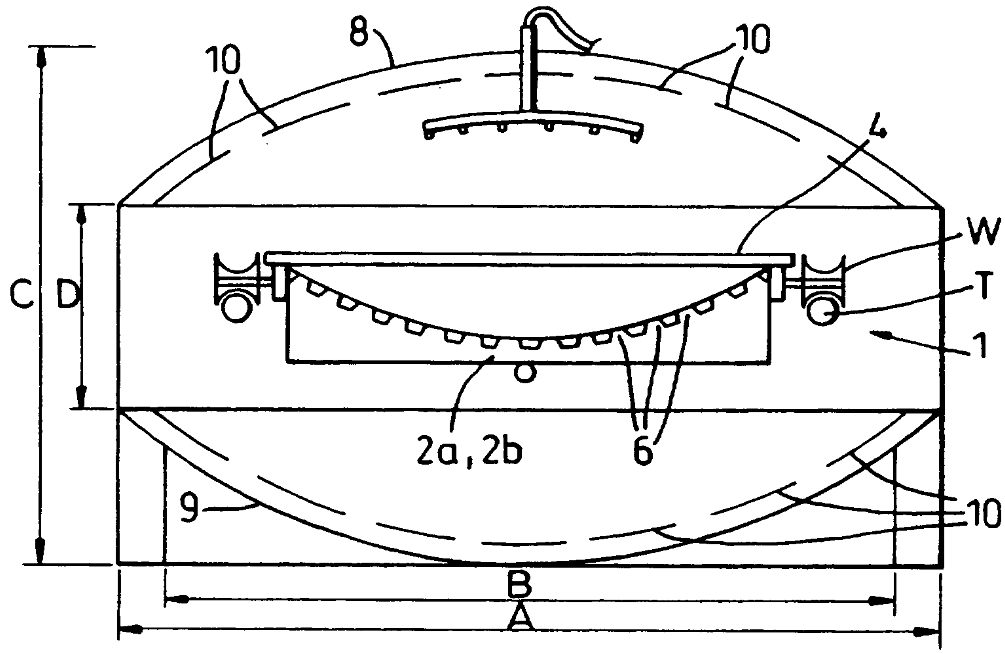

Fig. 1

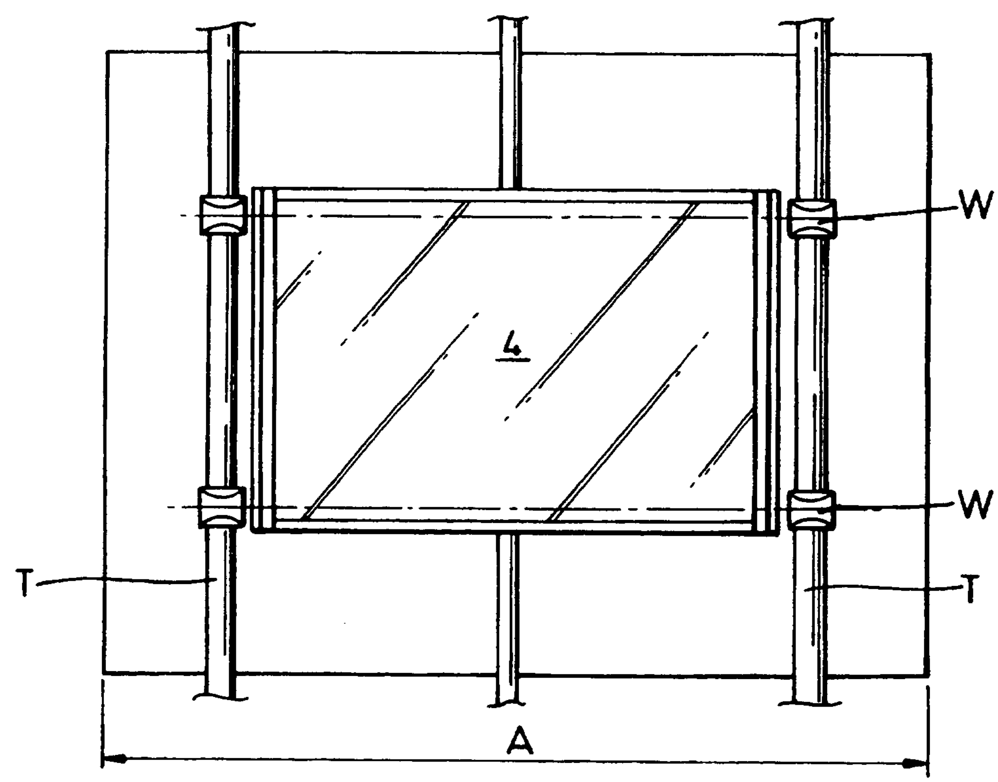

Fig. 3

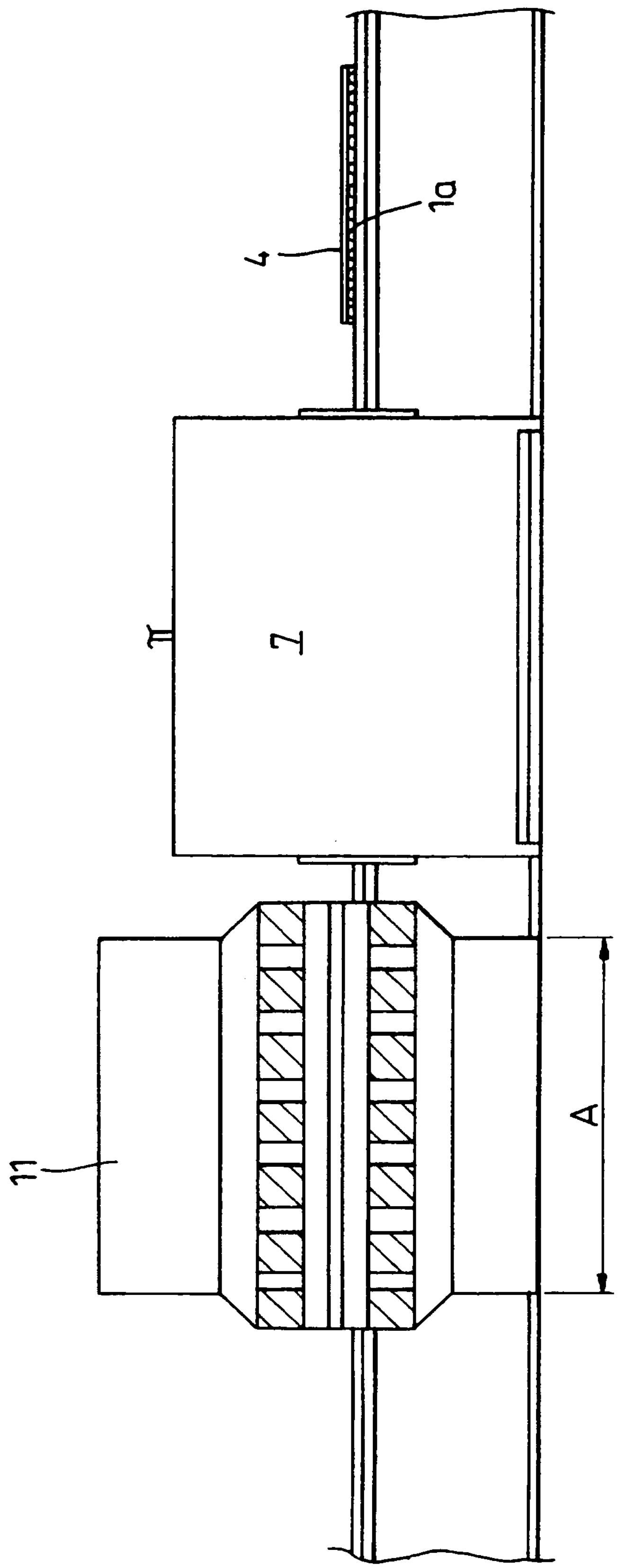

Fig. 4

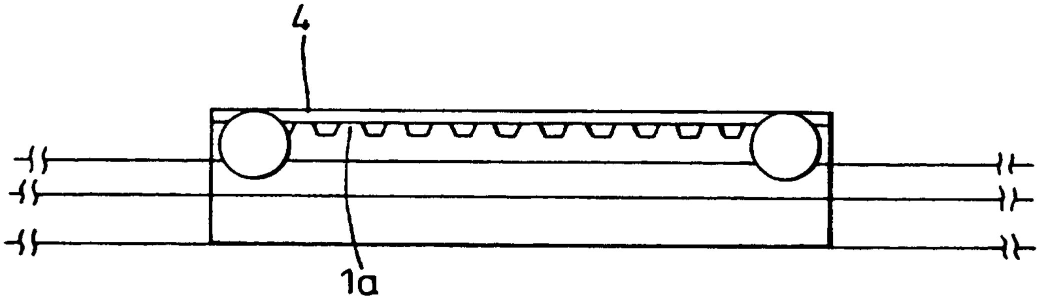

Fig. 2

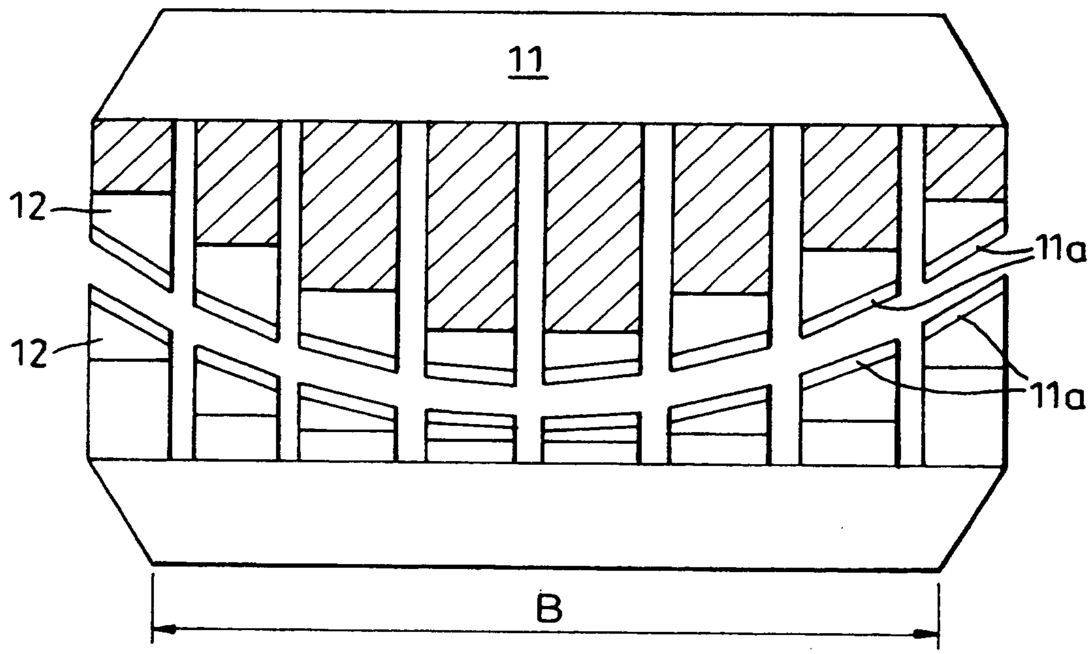

Fig. 6a

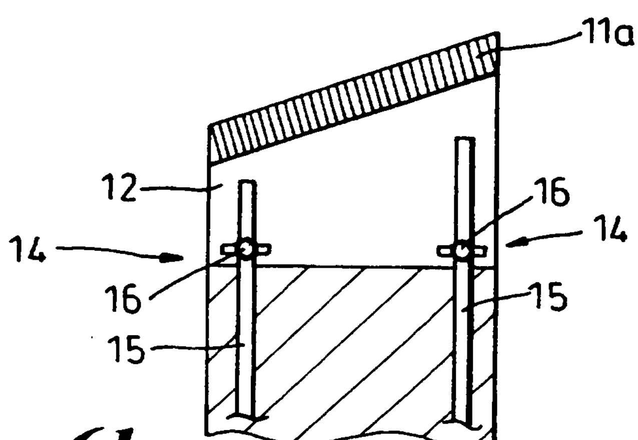

Fig. 6b

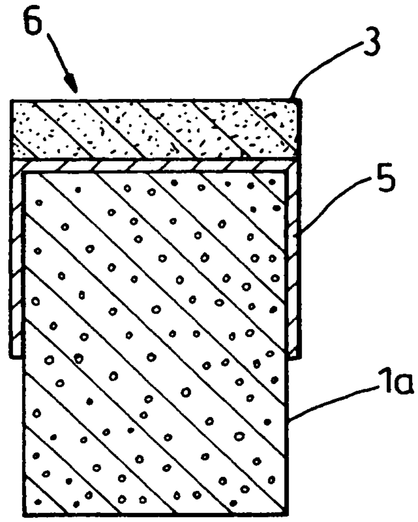

Fig. 5a

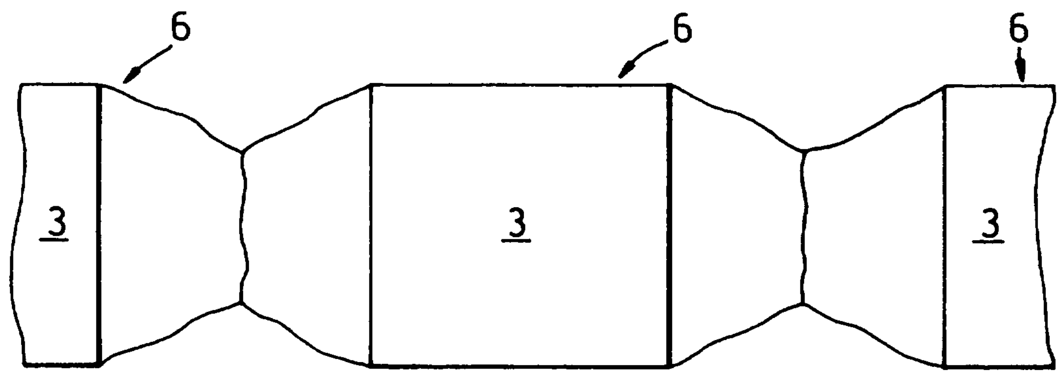

Fig. 5b

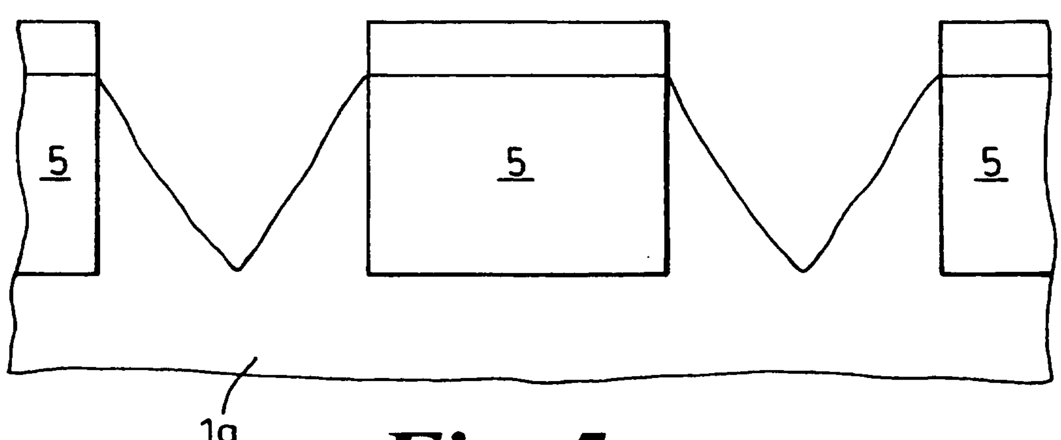

Fig. 5c

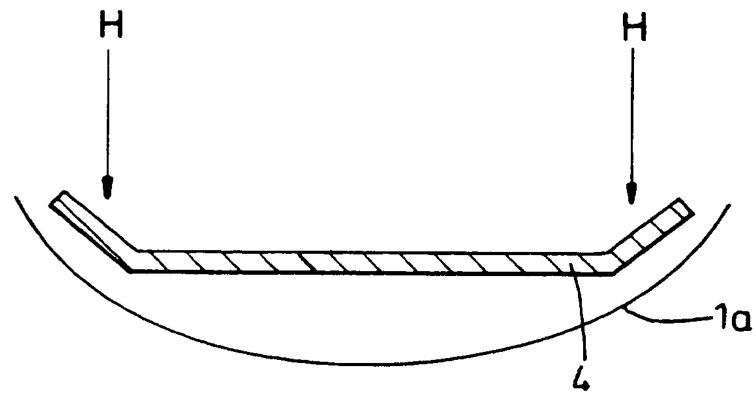

Fig. 7a

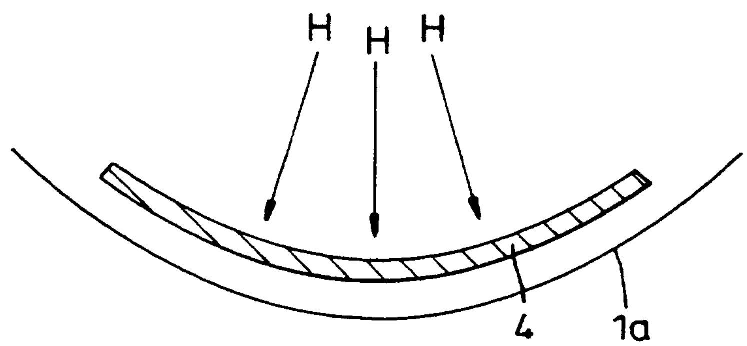

Fig. 7b

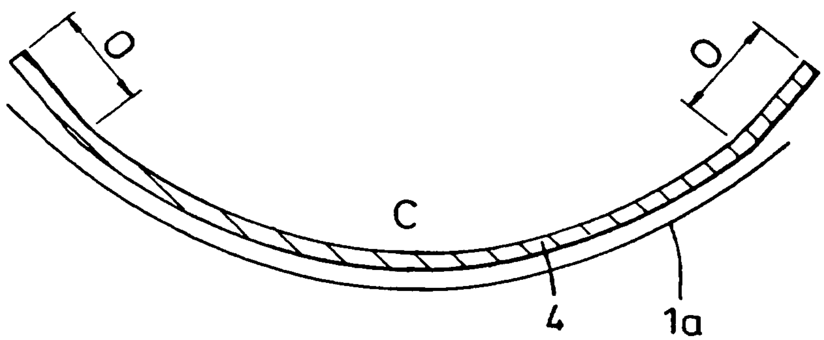

Fig. 7c

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METHODS AND APPARATUS FOR MAKING GLASS

The present invention relates to methods and apparatus for making glass, in particular, curved and heat-toughened (tempered) glass.

The term "shaped" is intended to include curving, bending or any alteration of a planar to non-planar configuration.

Tempered bent, curved or shaped glass has many uses and the demand for this material is increasing. Some examples of uses are: architectural, vehicles, ships and boats, furniture, retail and wholesale display, home appliances, and fencing.

In order to heat-temper glass, the glass is heated in a gas furnace and then cooled rapidly. The types of furnaces, methods of heat application and methods to cool the glass are many and varied.

A known method for producing tempered curved glass comprises the following steps.

i) a glass sheet is advanced on ceramic rollers through a gas furnace with heating elements arranged above and below the rollers;

ii) the heated glass is transported to a bending device which includes a plurality of adjustable rollers arranged to cooperate above and below the heated glass to bend the heated glass to the desired radius;

iii) the bent glass is then cooled rapidly.

A considerable problem with the above method is that small surface imperfections on the bending rollers are transferred onto the surface of the glass. Thus, the curved glass produced has an unsatisfactory optical

quality.

In addition, the above method is problematical because the glass has to be heated far in excess of its melting point, to around 660-670°C, so that it reaches the bending device at a suitable temperature. At such temperatures the glass is very molten and is readily distorted. To maintain a suitable glass temperature for bending the glass the bending device is provided with a series of gas flame heads which heat the glass until it has been curved by the rollers. Thereafter, the gas flame heads are closed and cool air is blown onto the glass via a plurality of air nozzles. It will be appreciated that the above method is complicated and extremely inefficient in terms of energy usage.

It is also known to use a rigid mould for bending the glass. As the glass is heated it bends or sags under gravity, or a vacuum, to conform to the radius of the mould. However, a problem with known moulds is that the area of the mould in contact with the glass causes surface marking of the glass and, more importantly, differences in temperature between the glass and the mould material can give rise to cracks or "chill vents" in the glass produced which can cause the glass to shatter after cooling. Such shattering can occur weeks after manufacture and is therefore potentially hazardous. To address the problem of chill-venting it is known to direct hot air around the mould beneath the glass. However, chill-venting and surface marking of curved tempered glass produced by known methods and apparatus are still major problems.

The present invention seeks to avoid or mitigate the problems of known methods and apparatus for producing shaped and tempered glass.

According to a first aspect of the invention there is provided apparatus for

producing shaped tempered glass comprising:

a mould comprising a frame arranged to support outer portions of a glass sheet to be shaped and tempered; wherein a heat transfer material is provided on a support surface of the frame to prevent the frame from contacting the glass directly in use.

Preferably, the frame comprises two curved side members arranged substantially parallel to one another.

Preferably, the heat-transfer material is sandwiched between the frame and an anti-marking material.

Alternatively, the heat transfer material and an anti-marking material are supported on an adjustable structure mounted to the frame.

The heat transfer material prevents or reduces the development of a temperature difference between the frame of the mould and the supported glass, thereby preventing or substantially reducing the likelihood of chill-venting when the glass is cooled after heating and shaping.

The presence of an anti-marking material between the glass and the heat transfer material reduces the likelihood of marking of the surface of the glass during the shaping procedure.

Preferably, the frame supports the glass sheet by means of a plurality of spaced apart support heads. This arrangement is preferred because it minimizes the area of contact between the glass sheet and the frame of the mould.

Preferably, the mould is made from a thermally inert material, that is, a

material which undergoes substantially no expansion or contraction at the temperatures involved in the glass shaping method. For example, a preferred material would withstand repeated exposure to high temperature (eg. up to 700-1000°C).

Preferably, the mould material can be machined easily to make a mould of any desired shape. Preferred mould materials include those comprising calcium silica.

Preferably, the heat transfer material is metallic, metals being able to withstand the tempering process, for example, by having a melting point above 550° centigrade (°C), such as mild steel, tin, stainless steel, iron, chrome and vanadium, being especially preferred. Conveniently, the heat transfer material has a thickness of approximately 0.5mm.

Preferably a ceramic or stainless steel material having a relatively smooth flat surface, such as stainless steel woven cloth is used as the anti-marking material.

Preferably, the anti-marking material is ceramic paper. A preferred ceramic paper for use in the invention comprises 85-97% by weight of synthetic ceramic fibre and 3 to 15% by weight of an organic binder. Such material is commercially available from Warren Bestobell of Chesterfield, England under the product name Ceramic Paper 1260°C-10901A & 10901B KOTHERM 1260°C.

The anti-marking material can be any material which conducts heat and prevents or substantially reduces marking of the surface of the glass at the temperatures involved in the glass shaping process. In this context, whether or not the material substantially reduces marking can be

determined by comparing the degree of marking produced on the surface of the glass in the presence or absence of the material when using the apparatus of the invention to make shaped tempered glass.

Conveniently, the thickness of the anti-marking material is from approximately 0.1mm to approximately 3mm, preferably from 1mm to 3mm.

Preferably the anti-marking material is mounted on the heat transfer material by means of an adhesive. When the anti-marking material is ceramic paper, it is preferred that the adhesive is a ceramic paste such as Carborundum Fiberfrax (Carborundum Co Ltd, St Helens, England).

Alternatively, the anti-marking material can be freely mounted or fixed mechanically into place.

Preferably, the thickness of the glass sheet to be curved and tempered is from approximately 3mm to approximately 25mm, more preferably from 6mm to 25mm.

Preferably, the surface area of the support heads is as small as possible to reduce the contact area with the glass to a minimum. Preferably the surface area of the support heads is from $6mm^2$ to $18mm^2$, and more preferably $6mm^2$ to $12mm^2$. The minimum surface area will vary depending on the thickness of the glass sheet to be bent. For example, when the glass sheet thickness is approximately 6mm, it is preferred that the surface area of each support head is less than $10mm^2$.

If the anti-marking material is in the form of a strip or band, it is preferable for the width of the strip to be 15mm or less. For example,

when using 6mm glass, it is preferred that the strip of anti-marking material is 4mm or less. Of course, a skilled worker will be able to determine the minimum support head surface area or anti-marking material strip width required for a given thickness of glass sheet using routine tests involving nothing more than trial and error.

To date, the apparatus of the invention has been used successfully to shape and temper every type of glass which has been tested, including glass formed from sodalime silica.

In use, the apparatus of the invention is provided in combination with heating and cooling means, which may be conventional.

A glass sheet is transported to a shaping station comprising apparatus according to the first aspect of the invention. The glass is supported on the support frame and heated rapidly using a suitable heater, such as Infra-Red (IR) heating elements emitting medium wave IR radiation, whereby the glass sheet sags under gravity to conform to the shape of the mould.

Typically, the glass as heated to more than 600°C, preferably approximately 625°C, until it emits infra red radiation.

The shaped glass and mould are then subject to rapid cooling so as to cause the glass to become tempered or heat strengthened as required.

This can be carried out in the furnace chamber or by moving the glass to a cooling zone separate from the furnace chamber.

Typically this is carried out by rapidly cooling the glass by application of volumes of moving air to both surfaces of the shaped glass by air blowers

arranged so as to effect even cooling to both surfaces of the glass. The air is at ambient temperatures, though "chilled" air at lower temperatures could be used if desired.

The air application method is essentially the same as known methods for tempering (toughening) of flat or shaped glass.

The tempered shaped glass sheet obtained is of an excellent quality, being substantially free of surface marks or blemishes and having a uniform stress distribution pattern which is vital if spontaneous breakage is not to occur.

In a second aspect the invention provides a method of making shaped and tempered glass comprising:

i) providing a mould in accordance with the first aspect of the invention;

ii) supporting a sheet of glass to be shaped on the frame of the mould;

iii) heating the glass so that it sags and conforms to the shape of the frame;

iv) subsequently cooling the glass to obtain a shaped tempered sheet of glass.

Preferably the glass is heated rapidly to temperatures exceeding 600°C, preferably 625°C, by means of one or more IR heating elements.

It is preferred that the heating means comprises an IR oven having a curved roof and floor so that infra-red heat can be focused into the centre of the oven.

Preferably a plurality of IR heating elements are arranged on either side of the sheet of glass to be shaped and tempered. Such an arrangement improves the uniformity of heating. Advantageously, the heating elements are independently controllable so that the heating of different areas of the glass sheet can be controlled precisely.

Preferably, the heating means is arranged to heat the outer portions of the glass sheet before or more than the central portion. Such heating improves the uniformity of bending of the outer portions of the glass sheet.

Preferably, cooling of the shaped glass reduces the temperature of the glass to 400°C or less as quickly as possible without breaking the glass. The air blowing and therefore the glass cooling time clearly depends on the thickness of the curved heated glass sheet.

It is preferred that cooling of the glass is achieved using a air blower device comprising an air fan connected to a plurality of air nozzles or air holes for directing the air onto the bent glass. Advantageously the nozzles or air holes are arranged above and below the glass sheet to ensure uniform application of air to the glass. Conveniently, the nozzles or air holes are mounted on a plurality of blast heads which can be moved relative to the glass sheet whereby each nozzle is a predetermined distance from the surface of the bent glass sheet to ensure a uniform application of air.

Preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a schematic end elevation of a mould and heating means

of apparatus of the invention;

Figure 2 is an side elevation of the apparatus of Figure 1;

Figure 3 is a plan view of the apparatus of Figures 1 and 2;

Figure 4 is a schematic showing the incorporation of apparatus of the invention into a shaped tempered glass manufacturing plant;

Figure 5a is an enlarged section showing the arrangement of supporting head, heat transfer material and anti-marking material according to a preferred embodiment of the apparatus of the invention;

Figures 5b and 5c are plan and side views of the arrangement shown in Figure 5a;

Figures 6a and 6b show a preferred air blowing unit for use in the method of the invention; and

Figures 7a, 7b and 7c illustrate a preferred method of the invention.

As shown in Figures 1 to 3 a preferred apparatus of the invention is a mould 1 comprising a frame 1a having two curved side members 2a, 2b arranged substantially parallel to one another.

The presence of an anti-marking material 3 between the glass 4 and the heat transfer material 5 reduces the likelihood of marking of the surface of the glass during the shaping procedure.

Preferably, the frame supports the glass sheet by means of a plurality of spaced apart support heads 6. This arrangement is preferred because it minimizes the area of contact between the glass sheet and the support frame of the mould.

Preferably, the mould is made from an insulation material which can withstand repeated exposure to high temperature without altering its shape. Preferred mould materials include those comprising calcium silica. These

materials can be machined easily to make a mould of any desired shape.

A 0.5 mm thick tin heat transfer material 5 is sandwiched between the support heads 6 and an anti-marking material 3 comprising a 1-2 mm thick layer of ceramic paper obtained from Warren Blastobell, Chesterfield, UK, which is adhered to the tin by means of a ceramic paste adhesive, Carborundum Fiberfrax.

The surface area of each support head with tin and ceramic paper mounted thereon is approximately $6mm^2$.

The mould material is porous and the tin is preferably mounted on the mould by fitting it over a support head and pressing it into the surface of the mould material. It will be appreciated that an adhesive could be used to mount the tin on the support head, but this is not preferred.

A preferred embodiment of a method of making shaped and tempered glass according to a second aspect of the invention comprises providing a mould 1 as described previously and supporting a sheet of glass 4 on top of the support heads 6.

The mould is attached to a stainless steel cable or mild steel chain and pulled along a mild steel track T on U-shaped cast iron wheels W into the centre of an IR oven 7 having a curved roof 8 and floor 9. The door of the IR oven is preferably opened and closed by means of a pneumatic ram arrangement (not shown) which can be operated rapidly to minimize heat loss.

A plurality of IR heating elements 10 are arranged on both sides of the glass sheet 4. Preferred IR heating elements and the IR oven can be

obtained from Mike Lockwood Furnaces, R & D Fabrications, and Overtons Electrical Contractors, all of Nottinghamshire, England. The IR elements 10 are conventional coiled resistant wires for emitting medium wave IR radiation. The heating elements 10 are operated independently by means of Eurotherm (RTM) thyristor controllers so that outer portions of the glass sheet are heated before or more quickly than the central portion. This ensures a smooth bending of the heated glass sheet under gravity against the mould. The glass sheet is heated to 625°C. Temperature sensors (not shown) are preferably provided to monitor the temperature of the glass and control heating via the Eurotherm (RTM) controllers.

The IR oven may also include an optional air inlet a which serves to circulate air in the oven to ensure uniform heating.

Figures 7a, 7b and 7c show a preferred method in which the outer portion O of the glass sheet is heated (H), Figure 7a, before or more than the central portion C, Figure 7b, to produce a shaped tempered glass sheet having excellent optical quality.

Figure 7c shows a possible product of a method in which the glass is heated uniformly, ie there is no earlier or preferential heating of the outer portion of the glass sheet. As shown the outer portion of the glass sheet produced is not curved.

After heating and shaping, the glass is pulled through into an air blower unit 11 comprising an air fan (not shown) connected to a plurality of air nozzles 11a mounted on blast heads 12 in a chamber 13. The nozzles 11a are arranged on both sides of the glass sheet and are movable independently by means of a adjustable height control 14 so that they can maintain a predetermined distance from the glass surface as the shape of

the glass changes on cooling. Preferably the distance is approximately 50mm. The air fan is operated to blow air at ambient temperatures through the nozzles and this cools the glass rapidly. If the distance from the glass surface is greater than 50mm the speed of the fan can be increased to compensate.

A preferred adjustable height control 14 is shown in Figure 6b. It comprises a pair of upright members 15 on which respective sides of a blast head 12 are mounted. Each side of the blast head can be moved along its member 15 to alter the distance between the glass surface and the nozzles 11a and the attitude of the nozzles as desired for any given sheet of glass. The position of the side of the blast head 12 on the member 15 is preferably fixed by means of a slide ring and locking bolt arrangement 16 as shown in Figure 6b.

The arrangement of the nozzles also permits glass of different thicknesses to be cooled effectively.

A 45 kW 1450rpm fan unit capable of delivering 50,000 cubic feet per minute of air is provided with a variable speed drive, such as a Danfoss (RTM) HV-AC Drive Type 3562. Suitable fan units can be obtained from Metrico Industrial Fans Ltd, Cheshire, England.

Preferably, the air blower unit comprises two square chambers with a fan unit at each end of each chamber. The fans are preferably connected to the nozzles of the blast heads by means of known ducting such as a Tico (RTM) M bellow (James Walker, UK).

The speed of cooling should be controlled so that the glass temperature is reduced from approximately 625°C to 400°C as quickly as possible

without breaking the glass. It will be appreciated that the rate of cooling will vary depending on the thickness of the glass sheet, but a skilled person will be able to determine the optimum rate of cooling for a given thickness of glass using routine tests involving nothing more than trial and error.

The air blower unit is preferably arranged so that a plurality of cooling zones is formed whereby the glass can be subjected to different rates of cooling, as desired.

In order to test the quality of the glass produced a skilled person may employ the common fragmentation test and particle count.

The test involves piercing the shaped glass sheet with a centre punch to release its inherent stress and counting the number of particles per 50 mm square. The particle count is related to the potential hazard should the glass sheet be broken. Preferably, the glass sheet should break into a large number of small glass particles. Larger particles are potentially more hazardous than smaller particles if they should hit a person.

Using methods and apparatus according to the invention, shaped tempered glass has been produced which has an average particle count of 50-55 per $50mm^2$ to satisfy the requirements of British Standard BS6206:1981, Class A.

The glass produced by the invention has an excellent optical quality, making it suitable for use in architectural applications.

The above test can be used by a skilled person to optimise the air fan speed and thereby the speed of cooling for a given thickness of glass,

It will be appreciated that the degree of bending is dependent on the mould shape and also the thickness of the glass sheet to be shaped. Successful shaping and tempering using the method and apparatus of the invention has been achieved using sodalime silica glass ("float glass") with the following range of sizes:

Table 1

Glass Type	**Thickness** (mm)	**Glass Sheet Size** (mm)		**Drop** (mm)	
Float Glass	6	2000x1800	-100x100	360	-50
Float Glass	8	2000x1800	-100x100	360	-50
Float Glass	10	2000x1800	-100x200	360	-25
Float Glass	12	2000x1800	-300x300	360	-25
Float Glass	15	1800x1800	-300x300	360	-20
Float Glass	19	1800x1500		360	
Float Glass	25	1200x1200		200	

In Table 1 the radius of curvature or "drop" which can be obtained is also indicated.

The preferred dimensions A to D indicated on the figures are: A = 2.3 metres (m); B = 2m; C = 1.5m; D = 0.5m.

CLAIMS

1. Apparatus for making shaped tempered glass comprising:

a mould comprising a frame arranged to support outer portions of a sheet of glass to be shaped and tempered; wherein a heat transfer material is provided on a support surface of the frame to prevent the frame from contacting the glass directly in use.

2. Apparatus as claimed in Claim 1 wherein the frame comprises two curved side members arranged substantially parallel to one another.

3. Apparatus as claimed in Claim 1 or 2 wherein the heat transfer material is sandwiched between the support surface of the frame and an anti-marking material.

4. Apparatus as claimed in any one of Claims 1 to 3 wherein the support surface of the frame comprises a plurality of spaced apart support heads.

5. Apparatus as claimed in Claim 4 wherein the surface area of the support heads is from $6mm^2$ to $12mm^2$.

6. Apparatus as claimed in any one of Claims 1 to 5 wherein the heat transfer material is metallic.

7. Apparatus as claimed in Claim 6 wherein the heat transfer material is selected from mild steel, tin, stainless steel, iron, chrome and vanadium.

8. Apparatus as claimed in Claim 6 or 7 wherein the thickness of the

heat transfer material is approximately 0.5mm.

9. Apparatus as claimed in any one of the preceding claims wherein the anti-marking material is ceramic paper.

10. Apparatus as claimed in any one of the preceding claims wherein the anti-marking material has a thickness of from 0.1mm to 3mm.

11. A method of making shaped tempered glass comprising:

i) providing apparatus as defined in any one of Claims 1 to 10;

ii) supporting a sheet of glass to be shaped and tempered on the frame of the mould;

iii) heating the glass so that it sags and conforms to the shape of the frame;

iv) subsequently cooling the glass to obtain a shaped tempered sheet of glass.

12. A method as claimed in Claim 11 wherein, initially, the outer portions of the sheet of glass are heated before or more than the central portion.

13. Apparatus for making curved tempered glass substantially as described herein with reference to one or more of Figures 1 to 5c.

14. A method of making curved tempered glass substantially as described herein, with reference to one or more of Figures 7a and 7b.

Amendments to the claims have been filed as follows

1. Apparatus for making shaped tempered glass comprising:

a mould constructed from a thermally inert material and including a frame arranged to support outer portions of a sheet of glass to be shaped and tempered; wherein a metallic heat transfer material is sandwiched between the support surface of the frame and an anti-marking material to prevent the frame from contacting the glass directly in use.

2. Apparatus as claimed in Claim 1 wherein the frame comprises two curved side members arranged substantially parallel to one another.

3. Apparatus as claimed in Claim 1 or 2 wherein the support surface of the frame comprises a plurality of spaced apart support heads.

4. Apparatus as claimed in Claim 3 wherein the surface area of the support heads is from $6mm^2$ to $12mm^2$.

5. Apparatus as claimed in any preceding claim wherein the metallic heat transfer material is selected from mild steel, tin, stainless steel, iron, chrome and vanadium.

6. Apparatus as claimed in any preceding claim wherein the thickness of the metallic heat transfer material is approximately 0.5mm.

7. Apparatus as claimed in any one of the preceding claims wherein the anti-marking material is ceramic paper.

8. Apparatus as claimed in any one of the preceding claims wherein the anti-marking material has a thickness of from 0.1mm to 3mm.

9. A method of making shaped tempered glass comprising:

i) providing apparatus as defined in any one of Claims 1 to 10;

ii) supporting a sheet of glass to be shaped and tempered on the frame of the mould;

iii) heating the glass so that it sags and conforms to the shape of the frame;

iv) subsequently cooling the glass to obtain a shaped tempered sheet of glass.

10. A method as claimed in Claim 9 wherein, initially, the outer portions of the sheet of glass are heated before or more than the central portion.

11. Apparatus for making curved tempered glass substantially as described herein with reference to one or more of Figures 1 to 5c.

12. A method of making curved tempered glass substantially as described herein, with reference to one or more of Figures 7a and 7b.

The Patent Office

19.

Application No:	GB 9625113.7	**Examiner:**	Jeremy Philpott
Claims searched:	1-14	**Date of search:**	30 January 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): C1M (MHF, MHM, MJD)

Int Cl (Ed.6): C03B: 23/023, 23/025

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	EP 0388249 A2	(Saint-Gobain Vitrage International) whole document, especially col 4 lines 35-46.	3, 6, & 7
X,Y	EP 0376509 A1	(Ford Motor Company) whole document, especially col 3 lines 8-32; col 3 line 54 to col 4 line 6; col 5 lines 12-32.	1 (X) 12 (Y)
Y	US 5388432 A	(Saint-Gobain Vitrage International) whole document, especially col 2 lines 37-44.	3, 6, & 7
Y	US 5069703 A	(Saint-Gobain Vitrage) whole document, especially col 2 lines 21-44, & Fig 2.	3, 6, & 7
X, Y	US 4556408 A	(PPG Industries Inc.) col 3 line 45 to col 5 line 65, & Figs 1-11.	1 & 4 (X) 3, 6, 7 (Y)
X, Y	US 4556407 A	(PPG Industries Inc.) col 3 line 61 to col 6 line 48, & Figs 1-11.	1 & 4 (X) 3, 6, 7 (Y)
X	US 3163514 A	(Pittsburgh Plate Glass Co.) col 3 lines 55-61, & Figs 1, 4 & 5.	1, 4, 6 & 7

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		